REMARKS

Claims 80-84 and 88-110 are pending in the present application. In the Office Action dated December 17, 2003, the Examiner rejected claims 80, 81, 88, 89, 96-101 and 105-110 under 35 U.S.C. 103(a) as being unpatentable over U.S. Patent No. 5,622,888, to Sekine et al. ("Sekine") in view of U.S. Patent No. 5,700,710, to Zenke ("Zenke"). The Examiner also rejected claims 83, 91, 94 and 103 under 35 U.S.C. 103(a) as being unpatentable over Sekine in view of Zenke as applied to claim 80, and further in view of U.S. Patent No. 6,077,742, to Chen et al. ("Chen"). Finally, the Examiner rejected claims 82, 84, 90, 92, 95, 102 and 104 under 35 U.S.C. 103(a) as being unpatentable over Sekine in view of Zenke as applied to claim 80, and further in view of U.S. Patent Publication No. US 2001/0001501 A1, to Lee et al. ("Lee"). Applicant disagrees with these rejections and wishes to clarify various distinctions of Applicant's invention over the cited art. Reconsideration of the invention is therefore requested in light of the following remarks.

In the remarks that follow, various technical differences between the references cited by the Examiner and the embodiments of the present invention are discussed. It is understood, however, that any discussion involving various embodiments of the invention, which are disclosed in detail in the applicant's specification, do not define the scope or interpretation of any of the claims. Moreover, any discussion of differences between the references cited and the various embodiments of the invention are intended only to help the Examiner to appreciate the importance of the claimed distinctions as they are discussed.

Applicant's invention exposes a conductive layer to an oxygen-inhibiting plasma prior to the formation of another layer or layers on the conductive layer to substantially reduce the association of oxygen with the conductive layer during formation of the other layer or layers. By reducing the amount of oxygen associated with the conductive layer, the electrical characteristics of a semiconductor device including the conductive layer are improved.

Figures 4 and 5 illustrate in-process semiconductor devices being formed by a process according to one embodiment of the present invention. As mentioned in the specification, for the purposes of explanation the in-process semiconductor device is assumed to be a capacitor in the process of being constructed. In Figure 4, the capacitor includes a first

conductive layer or 24, which may be formed from hemispherical silicon grain (HSG), formed over a substrate 22, and a dielectric 26 formed on the first conductive layer. In the examples of Figures 4 and 5, the dielectric 26 is formed from tantalum pentoxide Ta_2O_5. A second conductive layer 28 formed from tungsten nitride WN_x is then formed on the dielectric 26. The tungsten nitride layer 28 exhibits a tendency to associate with oxygen, particularly if that layer is exposed to oxygen prior to a third conductive polysilicon layer 30 being formed on the tungsten nitride layer 28. During subsequent processing of the capacitor, the oxygen contained in the tungsten nitride layer 28 can combine with silicon from the polysilicon layer 30 to form an unwanted silicon dioxide layer 36 between the tungsten nitride layer 28 and the polysilicon layer 30. For example, a thermal process step such as the formation of a borophosphosilicate glass (BPSG) layer 34 over the polysilicon layer 30, which occurs after the formation of the polysilicon layer 30, which may cause a reaction between the polysilicon layer 30 and the oxygen in the tungsten nitride layer 28 and thereby form the silicon dioxide layer 36.

The HSG layer 24 typically forms a first plate of the capacitor, the tantalum pentoxide 26 forms the dielectric of the capacitor, and the tungsten nitride layer 28 and polysilicon layer 30 form the second plate of the capacitor. With the formation of silicon dioxide layer 36, however, the capacitor now includes a first capacitor corresponding to the HSG layer 24, tantalum pentoxide 26, and tungsten nitride layer 28, and a second capacitor in series with the first capacitor, with the second capacitor corresponding to the tungsten nitride layer 28, silicon dioxide layer 36, and polysilicon layer 30. These first and second capacitors connected in series have a combined capacitance that is less than that of the ideally formed capacitor. As will be understood by those skilled in the art, the thickness of the silicon dioxide layer 36 affects the value of the combined capacitance.

In the capacitor of Figure 4, the thickness of the silicon dioxide layer 36 is greatly reduced by exposing the tungsten nitride layer 28 to an oxygen-inhibiting agent prior to the formation of the polysilicon layer 30 to thereby greatly reduce the association of the tungsten nitride layer with oxygen. The silicon dioxide layer 36 in the embodiment of Figure 4 is less than 10 angstroms thick due to the oxygen-inhibiting agent, while in a conventional capacitor shown in Figure 3 the silicon dioxide layer 36 is about 10-40 angstroms thick. In the capacitor

of Figure 5, the exposure of the tungsten nitride layer 28 to the oxygen-inhibiting agent eliminates the formation of the silicon dioxide layer 36 altogether.

The oxygen-inhibiting agent may be an N_2 and H_2 plasma, with the tungsten nitride layer 28 ideally being exposed to this plasma prior to exposing tungsten nitride layer to an atmosphere associated with the formation of the polysilicon layer 30 or prior to exposing the tungsten nitride layer to oxygen. As described in the specification, it is believed the exposure of the tungsten nitride layer 28 to the N_2 and H_2 plasma or any of the other oxygen-inhibiting agents stuffs the tungsten nitride layer grain boundaries with nitrogen or otherwise passivates the tungsten nitride layer, making the bonds at the grain boundaries less active and less likely to associate with oxygen. It should be noted that even if the tungsten nitride layer 28 is exposed to oxygen, the layer may thereafter be exposed to a reducing atmosphere, such as silane gas SiH4, prior to formation of the polysilicon layer 30 to thereby reduce the oxygen content of the tungsten nitride layer 28 and reduce the thickness of any silicon dioxide layer 36 thereafter formed.

In another embodiment discussed with reference to Figure 6, a first conductive layer such as a tungsten nitride layer 128 is deposited over a substrate 122 and a dielectric layer 126, such as a tantalum pentoxide layer, is deposited over the tungsten nitride layer. In this situation, the deposition of the tantalum pentoxide layer 126 may cause the tungsten nitride layer 128 to incorporate oxygen, reducing the capacitance of a capacitor including the tungsten nitride layer and tantalum pentoxide layer. Accordingly, in this embodiment of the invention, the tungsten nitride layer 128 is exposed to a N_2 and H_2 plasma or other oxygen-inhibiting agent before depositing the tantalum pentoxide layer 126. As previously described, the N_2 and H_2 plasma passivates the tungsten nitride layer 128 to thereby prevent oxygen from being incorporated within the tungsten nitride layer.

Another embodiment of the present invention is discussed with reference to Figures 7-10 in which an interposing layer 52 such as a tungsten nitride layer 52 is formed between a conductive line material 48 to enhance the electrical contact between the line material and the plug, promote adhesion of the line material within a container 50, prevent or slow the diffusion of materials across the tungsten nitride layer boundary, or serve some other purpose. As previously described, the tungsten nitride layer 52 may associate with oxygen after it is

formed and subsequent thermal processes may result in the formation of an oxide layer 54 formed between the tungsten nitride layer 52 and the line material 48. Because the oxide layer 54 is an insulator, this layer will adversely affect the electrical connection between the line material 48 and the plug 46. By exposing the tungsten nitride layer 52 to an oxygen-inhibiting agent or a reducing atmosphere prior to formation of the line material 48, the thickness of the oxide layer 54 is reduced to a thickness of less than 10 angstroms or entirely eliminated as illustrated respectively in Figures 9 and 10. Thus, in all embodiments a conductive layer is exposed to an oxygen-inhibiting agent or reducing atmosphere prior to another layer being formed on the conductive layer to thereby reduce an ability of the conductive material to associate with oxygen.

The Examiner has cited the Sekine reference. Sekine is directed to a method for producing a semiconductor device having a capacitive element with improved leak characteristics. In particular, the Examiner has cited the Sekine reference for disclosing that the first doped layer is polysilicon, and that the polysilicon layer may be roughened using HSG. The Examiner further notes that Sekine does not disclose exposing one of the conductive layers to phosphine or to hydrochloric acid (HCl).

The Examiner has also cited the Zenke reference. Zenke discloses a method of fabricating a capacitor having a roughened surface. The Examiner asserts that Zenke discloses that a polysilicon layer is roughened using HSG to form a first plate of a capacitor structure, and that the polysilicon is annealed in atmosphere that phosphine. Applicant notes, however, that Zenke does not disclose or fairly suggest exposing a conductive layer to HCl and further does not disclose or fairly suggest exposing the conductive layer to diborane.

Turning now to the claims, patentable differences between the claim language and the applied art will be specifically pointed out. Claim 80, as amended, recites in pertinent part, "A method of treating a wafer, comprising...depositing a first conductive layer onto the wafer...exposing the wafer in situ to a reducing environment...depositing a second conductive layer...and...*exposing the wafer to a material selected from the group consisting of diborane and HCl...*" (Emphasis added). As noted above, the Sekine and Zenke references fail to disclose this. Claim 80 is therefore allowable over the cited references. Claims depending from claim 80

are also allowable based upon the allowability of the base claim and further in view of the additional limitations in the dependent claims.

Claim 81, as amended, recites in pertinent part, "A method of treating a wafer, comprising...depositing a first conductive layer onto the wafer...exposing the wafer in situ to a reducing environment...depositing a second conductive layer...and...*exposing the wafer to a material selected from the group consisting of diborane and HCl...*" (Emphasis added). Again, Sekine and Zenke simply fail to disclose this. Claim 81 is therefore allowable over the cited references. Claims depending from claim 81 are also allowable based upon the allowability of the base claim and further in view of the additional limitations in the dependent claims.

Claim 88, as amended, recites in pertinent part, "A method of treating a wafer, comprising...depositing a first conductive layer onto the wafer...exposing the wafer to a reducing environment...depositing a second conductive layer...and...*passivating at least one of the first and second conductive layers by exposing the wafer to a material selected from the group consisting of diborane and HCl...*" (Emphasis added). Yet again, the applied references, either singly or in combination fail to disclose or suggest this. Claim 88 is therefore allowable over the cited references. Claims depending from claim 88 are also allowable based upon the allowability of the base claim and further in view of the additional limitations in the dependent claims.

Finally, claim 89, as amended, recites in pertinent part, "A method of treating a wafer, comprising...depositing a first conductive layer onto the wafer...exposing the wafer to a reducing environment...depositing a second conductive layer...and...*passivating at least one of the first and second conductive layers by exposing the wafer to a material selected from the group consisting of diborane and HCl...*" (Emphasis added). The Sekine and Zenke references do not disclose these compounds. Claim 89 is therefore allowable over the cited references. Claims depending from claim 89 are also allowable based upon the allowability of the base claim and further in view of the additional limitations in the dependent claims.

With respect to the Examiner's further rejections under 35 U.S.C. § 103(a), applicant respectfully submits that the foregoing amendments overcome these rejections by distinguishing the claims over the asserted combination of Sekine and Zenke, upon which these further rejections depend, as well as for still other reasons.

All of the claims remaining in the application are now clearly allowable. Favorable consideration and a timely Notice of Allowance are earnestly solicited.

Respectfully submitted,

DORSEY & WHITNEY LLP

Steve Arterberry

Steven H. Arterberry
Registration No. 46,314
Telephone No. (206) 903-8787

SHA:tlm/pep

Enclosures:
Postcard
Fee Transmittal Sheet (+ copy)

DORSEY & WHITNEY LLP
1420 Fifth Avenue, Suite 3400
Seattle, WA 98101-4010
(206) 903-8800 (telephone)
(206) 903-8820 (fax)

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